An Ecological Study of Valley-Forest Gastropods in a Mixed Mesophytic Situation in Northern Kentucky [1]

BY

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(7 Text figures; 3 Tables)

INTRODUCTION

THE MOLLUSCAN FAUNA of Kentucky is poorly understood (BICKEL, 1967), practically nothing having been written concerning the ecology of terrestrial species. Aquatic forms are even more poorly known. The objects of this report, then, are to present the findings of an ecological study carried out in a rather typical Cumberland Plateau valley system, attempt a correlation between mollusks present and HORTON'S (1945) valley classification as modified by KUEHNE (1962), record data which will be useful in determining the changes that occur as habitat disruption proceeds, and to compare the faunas of disturbed versus undisturbed areas.

A possible criticism of a portion of the study, i. e., that each station was only visited one time and hence during cold periods snails would be in hibernation whereas during warm months they would be active, is negated by the randomness and intensiveness of our collecting method. Furthermore, the authors do not confuse the concept of habitat and niche.

Historical Review of Studies on Kentucky Gastropods

As indicated by BICKEL (1967), almost all of the knowledge extant concerning Kentucky mollusks has been gleaned by workers outside the state. This is especially true in the case of snails. During the nineteenth century, Thomas Say and Rafinesque contributed periodic lists and descriptions, mostly from the Ohio River Drainage. A few other workers, notably Lea, described new species. During this century, very little has been accomplished. BICKEL (1965, 1966) conducted some brief ecological studies on some aquatic species. CLENCH (1926, 1962a, 1962b) and CLENCH & TURNER (1955) have presented significant findings in aquatic species, as have ROSEWATER (1959) and PRICE (1900). The latter paper also contained information on terrestrial species. Because of the extensive studies of GOODRICH (1921, 1929, 1934a, 1934b, 1934c, 1937, 1938, 1940, 1941), no fauna is better understood than the aquatic pleurocerids.

However, in terrestrial species, excluding the assorted records appearing in PILSBRY'S monograph (1939 - 1948), only CONKLIN (1957), HUBRICHT (1950, 1958a, 1958b, 1960, 1962a, 1962b, 1963a, 1963b, 1963c, 1964a, 1964b) and KAPLAN & MINCKLEY (1960) have made any attempt to study the diverse fauna of Kentucky. None of these works bears directly upon ecology.

History and Description of the Area

The deeply dissected, highly dendritic canyon system chosen for the study lies in the Cumberland Plateau of Wolfe and Powell Counties, Kentucky (Figure 1). The valley floors are mostly underlaid by undifferentiated Mississippian rocks, whereas the dissections themselves are through much-interdigitated Lee Sandstone underlaid by Breathitt formation. The latter formation is exposed on the floors, and it consists mostly of gray micacareous siltstones, subgraywacke sandstone, dark and light claystones containing ironstone concretions, some limestone (very sparse), chert, and coal (BRANSON & BATCH,

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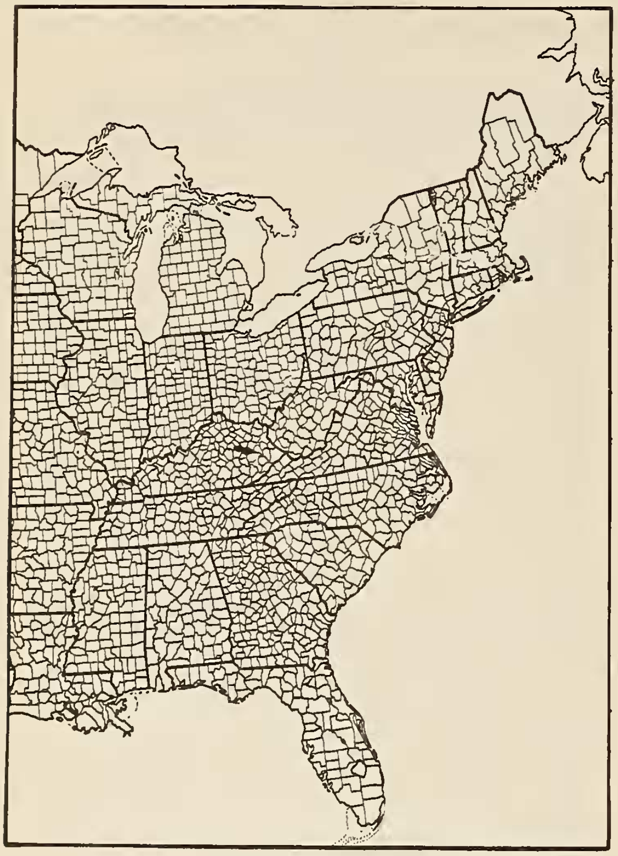

Figure 1

Map showing the Position of Wolfe and Powell Counties, Kentucky.

1968). The rugged, narrow valley with steep cliffs is supported by this formation. The overlying Lee Formation produces even more massive cliffs, 200 to 300 feet high (flat-faced and vertical), consisting mostly of resistant sandstone and siltstone, relatively little clay, ironstone, and limestone being in evidence.

The canyon system heads approximately 4/5 of a mile northwest of Pine Ridge, Wolfe County (Figure 2). The three main canyons were sampled, but the numerous side systems were not. The Tight Hollow system, consisting of first, second, and third order canyons, drains 0.558 square mile, and it is three-pronged, roughly Y-shaped. The south arm, which receives a short, deep bifurcation, heads at 1040 feet mean sea level (msl), and extends 2.4 miles to its confluence with the north arm. The headwater cliffs average slightly more than 200 feet in vertical height. Below this point, the cliffs are of variable height, but always steep, and the enclosed valley is narrow and rocky.

The northern arm heads at 1240 msl, then extends two miles to its confluence with the southern or lower one at 1030 feet. From this point, the lower arm extends 2225 feet to make contact with the Mill Creek system at 900 feet msl. Mill Creek meanders between steep walls for slightly in excess of 12 000 feet to open into the much wider canyon of the Middle Fork of Red River, picking up Doe Branch, Black John Creek, and Doublecave Branch en route.

The floor of these canyons is occupied by spring-fed perennial streams (see "collecting station" notes). Table 1 presents the physical and chemical characteristics of the streams. In Tight Hollow, the creek is small, ranging from 4 to 6 feet in width and from 1 to 6 inches (excluding a few pools) in depth at the headwaters. In the second order stretch, the creek widens to about 15 feet and ranges from 8 inches to 3 feet in depth. Below station 4, the creek runs in a bed averaging 30 feet in width, but the actual water course ranges from 30 inches to 15 feet, mostly very shallow, clear water. At the point where stations 4 and 5 join, there is a large pool of approximately 30 feet in diameter, 1½ feet in depth.

In the third order canyon, the stream averages 20 feet in width, 3 to 4 inches in depth, with pools up to 3 feet deep. Numerous small springs join the stream in this stretch, and the stream bed drops rapidly, about 12 feet in 30 linear feet. At the lower end of this station, there is a pool approximately 40 feet in diameter, and about 4½ feet deep, above which is a small waterfall. Below station 6, the stream is about 20 feet wide and varies from 6 to 12 inches in depth.

The portion of Mill Creek occupied by station 8 averages 12 feet in width and about 2 feet in depth. In the stretch designated as station 9, the stream has a tendency to become braided in places, but in general the channel averages about 17 feet in width and ranges from 3 inches to 3 feet in depth. Station 10 contains a rapidly dropping bed, and Mill Creek widens to about 30 feet, alternating between 2-foot pools and shallow riffles. Most of station 11 is occupied by Mill Lake (Figure 2). Above the lake, the stream is 25 to 30 feet wide and 14 inches deep, whereas at the earth-fill dam it is 65 feet deep.

The remaining 3 stations are in the fourth order canyon of Middle Fork of Red River. Here, the stream ranges from 30 to 50 feet in width and from 6 inches to 4 feet in depth.

The stream bottom in Tight Hollow consists of flat sandstone, deposits of sand, some organic debris, and sandstone boulders. In the Mill Creek canyon, the bottom

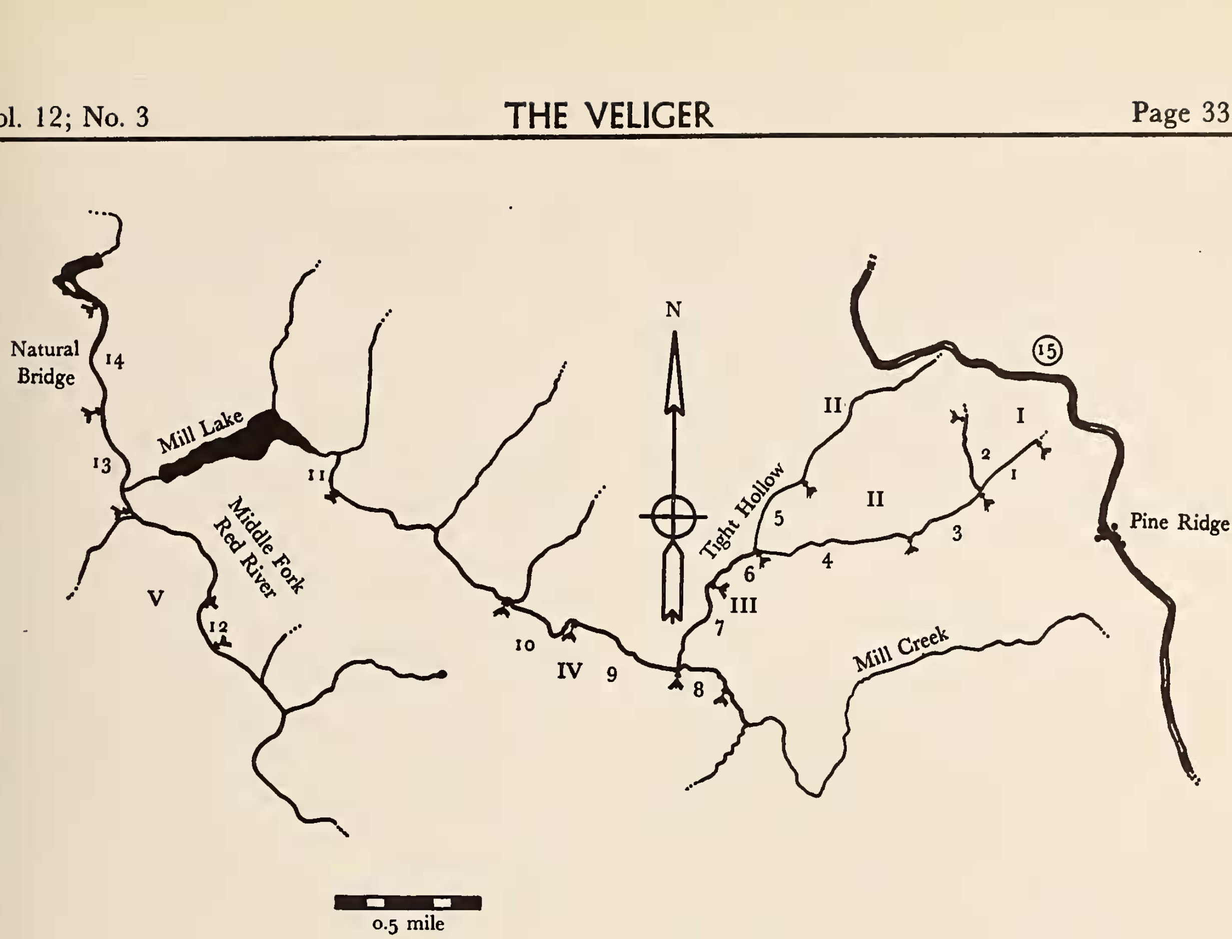

Figure 2

Map showing the Position of Collecting Stations in Tight Hollow, Mill Creek, and Red River Canyons, Wolfe and Powell Counties, Kentucky. Arabic numerals demark stations; Roman numerals indicate canyon-stream order (Horton System). Collections made midway between arrows (see text).

is primarily flat sandstone, small boulders, and large amounts of sand. The Red River bottom consists primarily of sand, gravel, and medium to small rocks, except at station 14, where large quantities of mud have accumulated.

Some of the general biotic conditions of these canyons were indicated by Branson & Batch (1968, 1969, and in press). The upper part of the system has never been occupied by man, notwithstanding a few abortive attempts to locate silver there at the turn of the century. Conditions are essentially relict and unmodified from, and including stations 1 through 5. The dominant trees are beech, eastern hemlock, tulip tree, red maple, northern dogwood, and umbrella magnolia on the south ridge; American holly is abundant from station 6 upgrade. From station 1 through 5, *Rhododendron* is exceedingly dense, up to 2117 main stalks per acre. Below station 5, the latter form is progressively replaced by mountain laurel. A similar relationship exists between hemlock and tulip trees, and hemlock versus pines (White and Virginia).

These conditions reflect the effect of commercial logging some 20 years ago. Below station 5, the valley has been logged, and at the junction of stations 7 and 8 the remains of an old farm are visible. Ecological conditions on this point are best described as old field.

Below Mill Lake, which is a trout-stocked fishing lake, Red River stations 12, 13, and 14, lie in the much-disturbed Natural Bridge State Park. Thousands of fishermen, campers, hikers and picnickers visit the area annually.

Of the ground vegetation, various species of Polypodiaceae, *Sedum, Lygodium, Lycopodium,* and numerous mosses are the most important in the undisturbed upper stations, with some dense stands of *Equisetum* along the creek, and thick growths of *Mitchella repens* Linnaeus, 1756, on the drier slopes. Downstream, several grasses have invaded the clearings, and *Salix* grows luxuriantly along the stream margin. In the undisturbed areas, there is a thick litter of leaves and needles, in addition to many logs and limbs in various stages of decomposition. Other than a little encrusting algae, there is no aquatic vegetation in the stream until Mill Lake is formed. There, a meagre growth of *Nitella* occurs in deep water, and sparse accumulations of *Spirogyra* elsewhere. Below the lake in Red River, the bottom is without rooted plants until station 14 is reached. As indicated above, the bottom at this station has considerable mud, and in backwaters considerable growths of *Typha angustifolia* LINNAEUS, 1756, and *Potamogeton crispus* LINNAEUS, 1756 occur.

METHODS

Field sheets and notes were prepared for each station, which included general descriptions, field numbers, and the material included in Table 1. The latter data were secured by means of tests included in "Standard Methods for the Examination of Water and Wastewater" (ORLAND, 1965). Turbidity was determined by means of a Hellige Turbidimeter, and water color was assayed by the platinum-cobalt method (LAMAR, 1949).

At each of the collecting stations delineated in Figure 2, a 12-foot wide swath, located at the center of each station, was hand-collected from one rim of the valley to the other. Fine-pointed forceps were utilized to secure small to minute specimens, and in some areas a set of graduated brass sieves were used to sift litter. Information on plant associations was obtained by means of random swaths.

COLLECTING STATIONS

Collections were secured from 14 sites. In the text following, specimens are referred to proper stations by numbers in parentheses. All specimens, unless otherwise indicated, are deposited in the Eastern Kentucky University Museum of Zoology.

Station 1. 26 February 1966. Valley narrow, V-shaped, between vertical, concave cliffs which rise over 200 feet; several old talus slides present; all boulders and rocks are sandstone with some small nodules of ironstone. Numerous fallen logs present. Vegetation dense, including mosses, liverworts, ferns; heavy shade by *Tsuga, Magnolia, Rhododendron,* and *Ilex.* Much ground seepage. Creek 4 to 6 feet wide, clear, running over bedrock, rubble, boulders, and sand, 1 to 1½ inches in depth, with a few shallow pools up to 2 feet in depth. Modest current.

Station 2. 5 March 1966. Valley narrow, V-shaped, the floor heavily littered with massive boulders, flat sandstones, and some topsoil washed in from above; forest litter deep and humid. Other conditions and vegetation approximately as at station 1. Creek varies from 6 to 15

Table 1

Physical and Chemical Data for Tight Hollow Creek, Mill Creek, and Middle Branch of Red River, Wolfe and Powell Counties, Kentucky (all temperatures in degrees Centigrade)

	Station Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hydrogen Ion conc. (pH)	6.98	7.05	7.08	6.85	7.10	6.91	7.16	6.98	7.01	6.56	7.09	7.51	7.27	7.52
O_2 (ppm)	10.74	11.46	10.85	10.93	11.12	10.78	10.97	8.72	8.78	8.18	9.02	8.78	9.25	8.37
% Saturation of O_2	80	88	87	97	91	92	91	90	—	90	119	113	123	110
Free CO_2 (ppm)				0.85	0.50	0.37	0.43	0.75	0.33	0.30	0.47	0.00	0.20	0.57
Phenolphthalein	0	0	0	0	0	0	0	0	0	0	0	1.83	0	0
Methyl Orange	17.0	16.83	11.17	11.83	7.75	9.75	25.17	11.75	17.83	24.17	42.83	57.33	65.33	43.0
Hydroxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbonate	0	0	0	0	0	0	0	0	0	0	0	3.67	0	0
Bicarbonates	17.0	16.83	11.17	11.83	7.75	9.75	25.17	11.75	17.83	24.17	42.83	55.50	65.33	43.0
Hardness (Total: Ca & Mg)	52.97	41.54	26.69	36.32	19.57	14.93	23.68	18.97	26.49	31.23	46.15	259.42	254.14	158.27
Air Temperature (°C)	2	5.5	15	10.05	10.0	10.75	7.8	19.7	—	21.5	34.0	23.7	32.0	30.2
Water Temperature (°C)	1.8	3.7	5	9.0	5.8	7.0	6.0	16.0	—	19.0	28.5	27.0	28.5	28.5
Soil Temp. (6″ depth, °C)	3.0	5.0	6.0	7.5	6.0	7.0	6.0	16.0	—	11.5	—	17.0	22.5	—
Turbidity (ppm)	—	—	4.25	43.3	7.33	2.90	3.33	14.25	1.0	0.77	0.36	0.41	1.23	1.53
Color (ppm)	—	—	—	—	15.5	15.5	10.0	25.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

feet in width, with several small cataracts over boulders (lacking in late summer) and a few pools up to 20 feet in diameter and 2 feet in depth; bottom of sand, boulders, and flat rock impregnated here and there with small white nodules; heavily overhung by *Rhododendron,* and several dead *Tsuga* logs have fallen into the stream from the steep sides.

Station 3. 12 March 1966. Cliffs less declivitous; valley U-shaped, now with a narrow flood plain containing much organic debris. Vegetation and other conditions similar to those of previous two stations. Creek, slightly meandering over bed of sandstone, rubble, small boulders, logs and debris, undercuts the cliffs in places, and some of the banks have fallen into the stream; alternation of shallow riffles with pools (2 to 3 feet in depth; one 50 feet in length), and a 4-foot fall is located near the center of the station. At lower end of the station, the valley again assumes its narrow character; stream bed inclines at a steeper angle, and widens to approximately 30 feet. Two small springs join the main stream at this point.

Station 4. 19 March 1966. Slope of valley walls less steep than at station 3. A modest flood plain of gravel, mud, sand, large and small sandstones, and deep organic litter, from 50 to 100 feet in width attends the stream. Stream bed about 30 feet wide, the flowing water from $2\frac{1}{2}$ to 5 feet in width, alternating between riffles (some 100 feet long) and pools, flowing over slightly terraced bedrock; much bank undercutting; a 10-foot fall in lower $\frac{1}{3}$ of station. Vegetation much the same as at previous stations.

Station 5. 26 March 1966. Nearly identical with station 4. *Rhododendron* forms canopy above water. Small amounts of algae in the stream. At the point where stations 4 and 5 meet, a pool 30 feet wide, $1\frac{1}{2}$ feet deep, and 150 feet long is produced.

Station 6. 2 April 1966. Valley wider at this point, and the slope of its walls more gentle; *Tsuga* partially replaced by white pine, and *Rhododendron* by *Kalmia*; forest floor more open with less litter. Stream averages 20 feet in width; bottom of bedrock roughed by numerous terraces, set at right angles to long axis, 2 to 12 inches in height; there is an alternation of sandbottomed pools and riffles; numerous springs fall into the stream. Below the middle of the station the stream bed declines rapidly, about 12 feet in a 30-foot stretch, and the bedrock contains many washed-out holes; near the lower end, the drop is about 17 feet in 100. At the point denoted by the lower arrow in Figure 2, a nearly circular pool has been gouged out. It is about 40 feet in diameter, has a sloping sand bottom, and is $4\frac{1}{2}$ feet in depth. The pool discharges via a short, straight channel over a 5-foot fall.

Station 7. April 1966. Similar to station 6, but valley reverts to the V-shaped configuration with vertical walls. Much dead wood, logs, and sandstone rubble and boulders. Considerable ironwood, beech, black alder, and red maple present; practically no *Rhododendron.* In the lower $\frac{1}{3}$ of the station, the stream goes underground for approximately 30 feet before emerging. Near the end of the station, the stream again submerges, runs underground for nearly 200 feet, and finally percolates up through sand and gravel to form a pool 4 feet deep, 55 feet long, and 12 feet wide. At the end of the station (confluence with Mill Creek), the valley widens abruptly, and a substantial flood margin is produced. On the left bank, and also partially adjoining Mill Creek, there is an old field sere, bearing numerous weedy plants, sumac, willow, young pine, cedar, *Lobelia,* and some other flowering plants.

Station 8. 23 April 1966. Mill Creek Valley. Valley wide, the slope of its walls moderate, with a flood plain of 200 to 300 yards in width gently inclined towards the creek; it is covered by grasses, sedges, sumac, various weedy species, dogwood, and a few maples. There are some boulders, small stones, rubble and organic silt. The creek, averaging 12 feet in width, runs in a bed of bedrock, rubble, sand, and gravel. Near the upper end of the stream, there are several oxbows, 2 to 5 feet in depth, with mud bottoms and weedy banks with numerous willows.

Station 9. 14 May 1966. Valley continues to widen, its walls to become lower. Evidence of an old silver mine on the left, about 100 yards downstream from the station's upper end. Flood plain similar to that of station 8. Stream about 7 feet wide, 3 or 4 inches deep, flowing over bedrock, gravel, sand, and small boulders. About 200 yards downstream, a large spring wells into the channel from the south bank. Below this, there are some large sandstone deposits along the south bank, and the channel tends to become braided.

Station 10. 22 May 1966. Essentially similar to station 9, but valley wider. In places, there are deposits of dead leaves and soil beneath 50-foot cliffs. Stream 20-foot wide, 3 to 18 inches deep, running over bedrock, sand, and gravel, alternating between pools and riffles at lower end.

Station 11. 25 June 1966. Valley impounded, mostly filled by Mill Lake. Around the margins of the lake are many dead trees, standing and fallen, and the early stages of succession are visible. Otherwise, the conditions are similar to those at station 9, although the valley is somewhat deeper and narrower. Above the lake, the stream bottom is of sand, and the water is about 25 to 30 feet in depth. At the point where the stream widens out into the lake, the bottom possesses much dead organic matter, and methane gas continuously bubbles up from the bottom. The lake is 65 feet deep at the dam. Living trees around the dam are mostly tulip trees, sycamores, sumac, and hawthorne.

Station 12. 11 June 1966. Middle Fork of Red River Valley. Valley much wider and, in places, the flood plain is nearly a mile wide. Agriculture practiced (mostly corn and tobacco), with numerous examples of old field succession: grasses, sedges, mullein, and weedy species. Dominant trees are willow, sycamore, tulip, hawthorne, some White and Virginia pine, and a few young *Tsuga*. The area is much disturbed. The river varies from 20 to 30 feet in width, with pools 3 feet in depth, and long stretches of six-inch water running over gravel, sand, small rocks, and beer cans.

Station 13. 2 July 1966. Valley approximately 1 mile in width, with a flood plain of approximately 80 feet on each side of the stream. General vegetation like that at station 12, but with large accumulations of dead leaves and drift-deposited twigs and limbs. Stream 20 to 40 feet in width, 2 to 7 feet deep; side pools contain mud, dead leaves. and organic ooze. The station ends in a sand-bottomed pool about 3 feet in depth, 45 in width, and 200 feet in length.

Station 14. 9 July 1966. Valley conditions similar to those at station 13, but trees more numerous: black walnut, willow, white pine, ash, box elder, dogwood, redbud, hawthorn. River banks heavily overgrown by *Kudzu*. Stream 30 to 50 feet wide, 2½ to 4 feet deep, running over sand, mud, and gravel. A low-water dam is placed at the upper end of the station (Figure 2), below which is a pool about 50 feet in diameter; its bottom is mostly muck, and along the sides are good growths of *Potamogeton, Carex, Spirogyra,* and narrow-leafed cattail.

Accounts of Species

A total of 1703 specimens was secured from the 14 sites delineated above. Represented in the collections were 12 families, 26 genera, and 52 species; two species are apparently new. These are described (not named) below. In the list which follows, the first numeral presented is the station designator; the numbers in parentheses represent the number of specimens collected at each site.

Polygyridae

Members of this family, represented by 3 genera and 14 species, accounted for 47.26% of the total collections, and it is thus the dominant molluscan taxon in the area, being approached only by the Zonitidae. Of the total collection, *Stenotrema* comprised 15.03%, *Mesodon* 23.67 %, and *Triodopsis* 8.57%. These data are broken down further in Table 2, and additional analysis is presented in the discussion. This pattern is adhered to throughout the paper.

Table 2

Percentage-Composition by Polygyrid Species in a Northern Kentucky Faunule

Species	% of total fauna
Stenotrema evardsi (Bland, 1856)	4.34
Stenotrema stenotrema (Pfeiffer, 1842)	5.46
Stenotrema angellum Hubricht, 1958	0.05
Stenotrema barbatum (Clapp, 1904)	3.75
Stenotrema leai (Binney, 1840)	1.17
Mesodon thyroidus (Say, 1816)	1.52
Mesodon zaletus (Binney, 1837)	0.05
Mesodon appressus (Say, 1821)	5.81
Mesodon sayanus (Pilsbry, 1906)	5.51
Mesodon ruglei (Shuttleworth, 1852)	10.74
Triodopsis tridentata (Say, 1816)	3.69
Triodopsis fraudulenta (Pilsbry, 1894)	1.93
Triodopsis denotata (Férrusac, 1821)	0.82
Triodopsis albilabris (Say, 1816)	2.11

Stenotrema evardsi (Bland, 1856)

Collecting sites: 1(1), 2(3), 3(1), 4(2), 5(24), 6(6), 7(5), 8(6), 9(15), 10(6), 12(1), 14(4)

This Appalachian snail characteristically occupies habitats along stream margins, valley slopes and mountains, mostly at elevations greater than 750 feet (Archer, 1948). Most of our specimens were found under decaying wood and in leaf litter. The species was more abundant in the middle and lower valleys than in the narrow portions above station 5 (0.9% to 2.56% from station 1 through station 4; 4.81% to 15.38% from station 5 through station 11). Below station 11 there was a sharp drop in numbers (1.78% to 3.33%). These latter stations have been grossly disturbed, so this may not be a valid observation. On the other hand, the altitude at the lower end of the study area is approaching the lower limits of *Stenotrema evardsi*'s altitudinal distribution.

Stenotrema stenotrema (PFEIFFER, 1842)

Collecting sites: 1(3), 2(6), 4(7), 5(7), 6(5), 7(10), 8(3), 9(27), 10(5), 11(7), 12(2), 13(2), 14(9)

Stenotrema stenotrema is a rather plastic species as regards habitat. We secured it in all sorts of places – beneath decaying hardwood and softwood logs, under bark, in leaf litter, beneath rocks – and at all altitudes. In the upper (excluding station 2) and middle stations, the population varied between 2.91% and 6.79%, reaching a higher percentage at and below station 9, 7.29% to 9.63%.

Stenotrema angellum HUBRICHT, 1958

Collecting site: 12(1)

The single specimen was found beneath a pile of dead bark near a tulip tree on a bluff above the stream. This is essentially the same type of habitat from which HUBRICHT (1958) removed the holotype. He (*loc. cit.*) indicated that the species was often found with *S. stenotrema.* However, in collections from other localities, we have found *S. angellum* only on the lower slopes, whereas *S. stenotrema* is often found at higher elevations as well.

Stenotrema barbatum (CLAPP, 1904)

Collecting sites: 1(1), 2(1), 3(5), 4(2), 5(3), 6(11), 7(24), 9(7), 10(3), 11(6), 12(1)

This species was entirely restricted to the lower sides of the slopes, where it was found under leaf litter, decaying wood, and to a less extent, under loose talus. It is difficult to compare our findings in this area with those secured elsewhere because of taxonomic confusion between this form and *Stenotrema hirsutum* (SAY, 1817). This latter is a smaller species, usually between 6.3 and 6.8 mm in diameter, lacking a buttress on the shell. All our specimens are larger than 6.9 mm (6.9 - 9.0 mm) in diameter, and all possess a buttress.

From station 1 through station 5, except at station 3, *Stenotrema barbatum* comprised only 9.97% to 1.92% of the molluscan fauna. At station 5, where the valley immediately re-assumes its narrow character, the population percentage drops to 1.92%. At the middle stations, 6 through 11, the percentage composition ranged from 4.68% to 9.64% (average 7.49%). In the lower 3 stations, more or less disturbed, the species represented less than 2% of the total population, or was replaced by the next species.

Stenotrema leai (BINNEY, 1840)

Collecting sites: 4(3), 6(1), 7(8), 9(6), 11(2), 13(1), 14(3)

Essentially a species of lowland hardwood forests, although sometimes found in coniferous situations, this species has a rather high moisture requirement and is thus limited to stream margins up to around 800 feet elevation. BASCH, BAINER & WILHM (1961) and others have found the snail in similar situations. The lowlands affinities of *Stenotrema leai* are well-illustrated by these findings. With the exception of station 4, where a small-pocket population exists, the snail is completely lacking in the upper stations (elevations above 1000 feet). From stations 7 through 14, *S. leai* comprised from 2% to 3% of the total terrestrial gastropod population.

Mesodon thyroidus (SAY, 1816)

Collecting sites: 9(7), 11(16), 13(7), 14(6)

PILSBRY (1940) indicated that *Mesodon thyroidus* was a lowland species, usually occupying humid habitats below 650 to 700 feet (occasionally up to 900 feet), and the observations presented here bear out the premise. Our specimens were either removed from leaf litter or found beneath decaying logs. In the lower valleys, *M. thyroidus* makes up between 3.5% and 6.25% of the fauna.

Mesodon zaletus (BINNEY, 1837)

Collecting site: 14(1)

Although station 14 is a lowland site, this probably does not reflect an altitudinal preference. PILSBRY (1940) found *Mesodon zaletus* up to 2000 feet above sea level in the southern Appalachians. Since the Lee Formation is very deficient in calcium, the absence of *M. zaletus* in most of this region probably reflects the lack of shell-building materials. The species is more or less abundant in regions to the south and west of the Upper Red River Drainage, and in the lower part of the drainage itself.

Mesodon appressus (SAY, 1821)

Collecting sites: 1(2), 2(7), 3(5), 4(12), 5(6), 6(10), 7(9), 8(3), 9(21), 10(5), 11(11), 12(2), 14(6)

According to PILSBRY (1940), who quoted a personal communication from Archer, *Mesodon appressus* is never abundant on non-calcareous soils; however, in the upper valleys, this species was more abundant percentage-wise than its 2 closest contenders, *M. ruglei* and *M. sayanus,* comprising on the average 8.55% of the fauna (1.94% to 12.82%). Below and including station 7, the population seldom exceeds 5% of the total, and when it does (11.45% at station 11, for example), the population is nearly always exceeded by *M. ruglei* or *M. sayanus* (see below). Most specimens were found burrowing beneath dead leaves or under stones and logs.

Mesodon sayanus (PILSBRY, 1906)

Collecting sites: 1(2), 2(1), 4(3), 5(8), 6(4), 7(17), 8(1), 9(9), 10(15), 11(9), 12(1), 13(15), 14(9)

This species develops its largest populations, compared with competitors, in the middle to lower slopes, down to around 100 feet. From the upper stations to the lower, there is a steady increase percentage-wise, ranging from 1.63% to 6.20% from stations 1 through 9. Below station 9, except for station 12 (which has been nearly denuded of trees by agriculture), the percentage composition ranges from 7.50% through 23.45%. At stations where the percentage ran low, the populations of *Mesodon ruglei* were larger. *Mesodon sayanus* is distinctly a forest-floor species. All of our specimens were found near the bases of hardwood trees, along the edges of logs and large boulders where considerable quantities of leaves had accumulated.

Mesodon ruglei (Shuttleworth, 1852)

Collecting sites: 1(5), 2(8), 3(4), 4(3), 5(10), 6(6), 7(53), 8(4), 9(42), 10(1), 11(18), 12(5), 13(10), 14(14)

Mesodon ruglei is the dominant polygyrid in the study area, and, indeed, one of the most abundant mollusks present. It seems to have no definite altitudinal preference. Pilsbry (1940) reported it to ascend up to 5000 feet in other regions. Only at 3 stations (1 (4.85%), 4 (2.91%), and 10 (1.56%), did its population fall below 5% of the total, averaging 11.83% (5.26% to 19.87%). The species likewise was found in various microhabitats: beneath large and small stones, in dry talus, burrowing in leaves, under decaying logs, and at the base of clumped grasses on the flood plains.

Triodopsis tridentata (Say, 1816)

Collecting sites: 1(7), 2(5), 3(6), 4(3), 5(7), 6(2), 7(19), 9(9), 10(1), 11(4)

This Appalachian species was said by Pilsbry (1940) to prefer limestone soils in hilly, shaded terrain and to avoid plains. However, Archer (1942) found *Triodopsis tridentata* abundant in sandstone uplands of low relief with pinewoods cover. These latter findings are essentially similar to ours, with the exception of differences in sylvan conditions. From our findings it is apparent that *T. tridentata* produces the largest populations in the uplands (6.79%, 8.77%, and 15.38% at stations 1, 2, and 3, respectively), becoming much less abundant in the lower ends of the valleys, except in isolated situations at middle altitudes (station 7: 6.93%), 1.53% to 4.16% of the total population. Below station 11 it is replaced by the following species.

Triodopsis fraudulenta (Pilsbry, 1894)

Collecting sites: 12(3), 13(15), 14(15)

Very little is known concerning the habitat requirements and ecology of this species. It is the dominant *Triodopsis* in the lower valleys (5.45%, 13.39%, and 12.50% at the 3 stations), where we found it primarily on afternoon-shaded slopes under leaves and decaying wood. Kahn & Kemp (1930) reported the species as more common on lower slopes than in the highlands.

Triodopsis denotata (Férussac, 1821)

Collecting sites: 7(4), 9(8), 10(1), 13(1)

This is is another distinctly lowlands species, as shown by our records. In fact, it was found only on the flood plains beneath water-deposited debris and logs. At the 4 stations listed above, it was never abundant (1.45%, 3.70%, 1.56%, and 0.89%, respectively), and these findings coincide with the senior author's observations at other Kentucky localities. As shown in Table 2, *Triodopsis denotata* comprised only 0.82% of the total molluscan fauna, only slightly more abundant than *Stenotrema angellum* and *Mesodon zaletus.*

Triodopsis albolabris (Say, 1816)

Collecting sites: 1(1), 4(9), 5(2), 6(3), 7(8), 8(2), 9(5), 10(2), 11(3), 12(1)

With the exception of station 4, where the population amounted to 8.73% of the total, *Triodopsis albolabris* is not abundant at any sampled locality in the valley system (0.97% to 3.27%). Pilsbry (1940) found the species to be scarce on sandstone substrate in the Catskills. Our specimens were found beneath accumulations of leaves in rock crevices, at the bases of trees, and beneath logs.

Haplotrematidae

Haplotrema concavum (Say, 1821)

Collecting sites: 2(1), 4(1), 6(3), 7(20), 8(7), 9(11), 10(1), 11(9), 12(10), 13(7), 14(11)

This is a common species of bluffs overlooking streams, especially on the lower slopes where leaf mold and woody debris abound. It is heavily preyed upon by shrews and *Peromyscus,* and in turn preys upon polygyrids. The populations were relatively small in upland situations, ranging from 0.97% to 2.63% from station 1 through station 7. From station 8 downward, the populations were much larger, sometimes attaining dominant numbers, such as those at 8 and 12 (11.47% and 18.18%, respectively), averaging 6.19%. *Haplotrema* accounted for 4.75% of the total fauna.

Zonitidae

The 8 genera in our collections accounted for 38.52% of the total fauna. Two genera, *Mesomphix* (13.44%) and *Ventridens* (12.74%), are responsible for most of the population, with *Retinella* (6.04%), *Gastrodonta* (3.52%), and *Striatura* (1.40%) ranking third, fourth, and fifth. The remaining 3 genera produced the following relationships: *Paravitrea* (0.99%), *Zonitoides* (9.35%), and *Euconulus* (0.17%). Similar data are presented for individual species in Table 3.

Table 3

Percentage-Composition by Zonitid Species in a Northern Kentucky Faunule

Species	% of total fauna
Euconulus chersinus (Say, 1821)	0.17
Retinella wheatleyi (Bland, 1883)	1.64
Retinella indentata (Say, 1823)	0.05
Retinella carolinensis (Cockerell, 1890)	0.88
Retinella cryptomphala (Clapp, 1915)	3.46
Mesomphix inornatus (Say, 1821)	3.99
Mesomphix perlaevis (Pilsbry, 1900)	6.92
Mesomphix vulgatus (H. B. Baker, 1933)	0.29
Mesomphix cupreus (Rafinesque, 1831)	1.93
Mesomphix capnodes (Binney, 1857)	0.29
Paravitrea species	0.05
Paravitrea multidentata (Binney, 1840)	0.11
Paravitrea placentula Pilsbry, 1946	0.05
Paravitrea capsella (Gould, 1851)	0.64
Paravitrea species a	0.05
Paravitrea species b	0.05
Gastrodonta interna (Say, 1822)	3.52
Ventridens demissus (Binney, 1843)	12.74
Zonitoides nitidus (Müller, 1774)	0.17
Zonitoides arboreus (Say, 1816)	0.17
Striatura ferrea Morse, 1864	1.40

Euconulus chersinus (Say, 1821)

Collecting sites: 7(2), 12(1)

Euconulus is not, according to our studies, a snail of the dense forests. Our specimens were secured from clumps of grass in clearings. Archer (1939) described the species as being characteristic of the grassy slopes of old gullies in Michigan.

Retinella wheatleyi (Bland, 1883)

Collecting sites: 4(4), 5(6), 6(2), 7(10), 9(4), 10(1), 11(1)

Although widespread in the upland and middle stations, *Retinella wheatleyi* was not found to be the dominant member of its genus. The snail was relatively more abundant from station 4 through 7 (1.75% to 3.88% of the total fauna) than from station 9, 10, and 11 (1.04% to 1.56%). The species lives primarily on the lower slopes just above the stream, and on the flood plain, beneath leaves, logs, rocks, and other moisture-conserving structures.

Retinella indentata (Say, 1823)

Collecting site: 1(1)

A single dead shell was collected at this site, and it probably washed into the canyon from above.

Retinella carolinensis (Cockerell, 1890)

Collecting sites: 7(1), 8(5), 9(6), 12(3)

Pilsbry (1946) related that the type locality for this species was the lower slopes of Roan Mountain (Great Smokies), and he further stated that the species was probably found only on the lower slopes of protected valleys. In this we concur. We did not secure specimens until station 7, where the population was meagre (0.36% of the total). The percentages at stations 8, 9, and 12 were 8.19, 4.44, and 5.46, respectively. An additional interesting observation is, when *Retinella carolinensis* occurs sympatrically with *R. cryptomphala,* the former species tends to replace the latter. At stations 8, 9, and 12, the population percentages for *R. cryptomphala* were 3.27, 3.70, and 3.63, respectively.

Retinella cryptomphala (Clapp, 1915)

Collecting sites: 1(2), 2(4), 3(5), 4(1), 5(2), 6(6), 7(14), 8(2), 9(9), 10(1), 11(4), 12(2), 13(7)

Not only did this species occupy varying habitats – leaf litter, decaying logs, clumps of grass, the undersides of rocks – but it was found at all elevations, and from a percentage comparison there seemed to be no differential regarding preferences, other than the relationship mentioned above. The densest population, in relation to the total fauna, occurred at station 3. However, this reflects the decreased numbers of other species present rather than an absolute increase in *Retinella cryptomphala.* Such local variations are common in land snails, and are probably responses to edaphic conditions.

Mesomphix inornatus (Say, 1821)

Collecting sites: 8(3), 9(14), 10(6), 11(14), 12(3), 13(8), 14(8)

Pilsbry's statement concerning the habitat of this species, i. e., "moist, shaded slopes and ravines . . . among leaves and dead wood," is supported by our findings. Moreover, the absence of the species from the uplands and head-valleys is striking. After its first appearance at station 8, the species was present in dominant to co-dominant numbers (4.91% to 14.58%), often sharing its position with the next species. We did not secure specimens from the valley rim or upper slopes; all specimens were found at the lower levels.

Mesomphix perlaevis (PILSBRY, 1900)

Collecting sites: 1(4), 2(6), 3(3), 4(3), 5(5), 6(13), 7(27), 8(10), 9(9), 10(1), 11(3), 12(5), 13(10), 14(12)

Found under dead leaves and decaying wood in the middle to lower slopes at every station, and ranging from 1.56% to 16.39% of the fauna, this species has the widest ecological distribution of any *Mesomphix* in the area. As indicated above, in some areas it occupies co-dominant status with *M. inornatus.* There did not appear to be preference for the small, heavily shaded valleys over the wider, less heavily shaded ones, although the average percentage of the total fauna from station 1 through 7 was 7.06 contrasted with 7.75 for stations 8 through 14.

Mesomphix vulgatus (H. B. BAKER, 1933)

Collecting site: 9(5)

Because of the close-set spiral rows of microscopic papillae on the upper and lower surface of the last whorl, these 5 specimens were tentatively identified as this species. However, as HUBRICHT (1962b) pointed out, diagnoses based solely on shell characteristics in this group are always open to question. Nevertheless, the shells are nearly identical with ones from which the soft anatomy was dissected. *Mesomphix vulgatus* is, with the next two species, a member of third-order valley faunas, seldom being found in the smaller, drier first and second order systems. Wherever we have found the species accompanied by *M. perlaevis* or *M. inornatus,* or both, it has always been slightly to greatly outnumbered by them.

Mesomphix cupreus (RAFINESQUE, 1831)

Collecting sites: 2(5), 9(2), 10(5), 11(2), 12(2), 13(9), 14(8)

Regardless of the fair-sized sub-colony at station 2 (living in a pocket of deep humus against a fallen tulip tree), *Mesomphix cupreus* characteristically is a middle to lowland species, as evidenced by our percentage array from stations 9 through 14: 1.48, 7.81, 2.08, 3.63, 8.03, 6.65, respectively. PILSBRY's (1946) habitat observations coincide essentially with ours: "usually found partially buried in damp humus, under a layer of dead leaves."

Mesomphix capnodes (BINNEY, 1857)

Collecting sites: 13(2), 14(3)

Our 5 specimens were removed from deep piles of dead hardwood leaves on the west slope of the valley; both sites were well shaded. Although we did not carry our observations on into the lower Red River System, we have collected the species from several loci since, always in subordinate numbers. *Mesomphix capnodes* appears to be another species of valleys of at least third-order magnitude.

All of the *Paravitrea* specimens listed below were secured from similar situations, i. e., from the interstices of moist, deeply placed talus near the point where the slopes leveled out into the floor of the valley. With the exception of *P. capsella* (8.14%), none of the species was secured in large numbers. The following percentages were obtained: *P. multidentata* (0.60% and 1.04%), *P. placentula* (0.60%), *P.* species a (0.60%) and *P.* species b (1.75%). Although too few specimens were found to allow derivation of ecological generalizations, the records are important from the standpoint of succession (discussed below).

Paravitrea species

Collecting site: 4(1)

A single specimen, too immature to identify.

Paravitrea multidentata (BINNEY, 1840)

Collecting sites: 9(1), 11(1)

Paravitrea placentula lithodora PILSBRY, 1946

Collecting site: 9(1)

Heretofore known only from Pine Mountain in Harlan County, this form probably merits specific recognition.

Paravitrea capsella (GOULD, 1851)

Collecting site: 9(1)

The exact relationship of this species to its western counterpart in the Ozarkian-Ouachitan region, *Paravitrea significans* (BLAND, 1866), is quite hazy and in need of detailed study.

Paravitrea new species? a

Collecting site: 2(1)

Shell small, pale yellowish, sub-shining; spire nearly flat, with very shallow sutures minutely rebordered by transparent shell material; 5½ whorls, rather flat-sided, curving gently to the sutures, the last slightly but definitely expanded; umbilicus deep, slightly lunate, narrow, the central portion about 9 times in diameter, but expanding in the last whorl to about 5 times in diameter; aperture deeper than wide, lunate; lip thin, simple; first whorl smooth, on remaining ones growth striae raised, irregular, becoming nearly regular on last two whorls; spiral, incised sculpture minute above, more or less obvious on otherwise smooth base; about one-third the way in from aperture there is a transverse band of 5 very low, contiguous tubercles.

Diameter 2.7 mm; height 1.3 mm; umbilical diameter 0.5 mm.

Deposited in the Field Museum of Natural History, Chicago; No. FMNH 155477.

This form is most closely related to *Paravitrea metallica* Hubricht, 1963 (Hubricht, 1963 c), being similar in size, whorl configuration, and in possessing an expanded last whorl. It differs from it in possessing a larger umbilicus, more regular sculpture, in having its aperture higher than wide, and in having more and differently arranged shell teeth. The teeth are arranged in one or two pairs in *P. metallica,* and the aperture is wider than high in that species.

Paravitrea new species? b

Collecting site: 9(1)

Shell small, very pale tan, glistening; spire barely convex, with shallow sutures, not re-bordered; whorls 5½, slowly expanding; upper periphery of body whorl slightly angular, base well-rounded; umbilicus deep, well-like, displaying all whorls, the central hole about 8½ times in diameter, expanding to about 4 times in the last whorl; aperture only slightly wider than high, simple, toothless; nucleus of 1½ whorls, smooth; sculpture of nearly regular growth striae and radial grooves, crowded.

Diameter 2.5 mm; height 0.9 mm; umbilical diameter 0.4 mm.

This species appears to be most nearly related to *Paravitrea tantilla* Hubricht, 1963 (Hubricht, 1963c) by way of the shallow sutures, slowly increasing whorls, and apertural and lip characters, but differs from that species in possessing more regular sculpture, a larger umbilicus, much smaller size (this form has nearly the same number of whorls as *P. tantilla* but is 1.2 mm smaller), and by lacking shell teeth.

Gastrodonta interna (Say, 1822)

Collecting sites: 1(11), 2(1), 4(2), 5(13), 6(2), 7(4), 9(10), 10(1), 12(1), 13(5)

Practically nothing has been published concerning the ecology of this, one of the most distinctive genera of North American snails. It lives on shaded slopes beneath dead leaves, although it seems to avoid *Rhododendron* and mountain laurel. At station 1 we found it abundantly beneath white pine needles. Archer (1942) also found the species associated with pine woods. There may be a slight preference for smaller valleys over the larger ones. The average composition-percentage in the upper valleys (stations 1 through 7) was 4.35% (1.45% to 10.67%), whereas in the lower ones (stations 9, 10, 12, 13) it was 3.46% (1.56% to 6.02%). However, sampling error could account for this small difference.

Ventridens demissus (Binney, 1843)

Collecting sites: 1(28), 3(4), 4(30), 5(56), 6(33), 7(31), 8(24), 9(5), 10(4), 12(1)

Ventridens was absolutely the single most-abundant species present in the study area from station 8 upward, and is mainly responsible for placing the Zonitidae as the second most abundant family. By station, the relative percentages were (station numbers in parentheses): (1) 27.18, (3) 10.25, (4) 29.12, (5) 35.89. (6) 28.94, (7) 11.31, (8) 39.34, (9) 3.01, (10) 6.25, and (12) 1.81. A sharp decrease in abundance was noted from station 9 downward, a trend we have also noted elsewhere. Our specimens were collected mostly from the upper and middle slopes, beneath dead leaves and logs. Such large populations are common in the genus. Mayer (1965), for example, reported one specimen of *V. suppressus* (Say, 1829) per square inch of log surface in Pennsylvania.

Zonitoides nitidus (Müller, 1774)

Collecting sites: 1(1), 2(2)

These specimens, representing 0.97% and 3.50% of the total populations at the 2 stations respectively, were found beneath dead leaves just above the stream margin. Pilsbry (1946) indicated that the species was generally found near water in lowland situations, never in upland woods, and Archer's (1939) observations were essentially the same in Michigan.

Zonitoides arboreus (Say, 1816)

Collecting sites: 4(1), 7(2)

The specimen from station 4 was found under a dead log on the flood plain, and those from station 7 under slabs of sandstone about half-way up the slope. Although *Zonitoides* enjoys a much wider ecological range, up to at least 10000 feet in the west, and down to sea level in the south, it is never found far from moist situations. Usually, the species is found in or around decaying wood. At these 2 stations, the small numbers represented only 0.97% and 1.14% of the population, but in other localities we have it to constitute as much as 20%. The species has a very erratic distribution within a given area.

Striatura ferrea Morse, 1864

Collecting sites: 1(8), 3(4), 4(2), 5(2), 8(2), 11(3), 13(3)

Following the same sequence as above, the composition percentages at each station were: 7.76, 10.25, 1.94, 1.28, 3.27, 6.25, and 2.67. There does not appear to be definite correlation between valley magnitude and the presence of this small mollusk. Since the specimens all came from the valley floors, under wet to damp leaves and decaying wood, conditions near to or at dew point perhaps limit the species' distribution.

Limacidae

Only a single species in this family was collected, representing only 0.70% of the total collection.

Deroceras reticulatum (Müller, 1774)

Collecting sites: 1(1), 4(10), 8(1)

All specimens of this widespread exotic species (Getz, 1959) were found near the stream beneath decaying wood; the 10 at station 4 were collected from an old U. S. Forestry marker. The percentages at the 3 stations were: 0.97, 9.70, and 1.63.

Endodontidae

Sixty-two specimens, or 3.61% of the total, were collected. The genus *Discus* was most abundant, 2.75%, with *Anguispira* (0.58%), *Helicodiscus* (0.17%), and *Punctum* (0.11%) in less quantities. Since each genus, except *Discus,* was represented by single species, the percentages were the same at the specific level. In *Discus, D. patulus* represented 2.70% of the population, and *D. bryanti* only 0.05%.

Anguispira alternata (Say, 1816)

Collecting sites: 11(6), 12(2), 13(1), 14(1)

Our specimens are very definitely the lowland form termed *angulata* by Pilsbry (1948). They were collected on the south slopes just above the stream, from beneath decaying logs. This propensity for wood was also noted by MacMillan (1940). Percentage-wise, the species was most abundant at station 11 (6.25%), and decreased in abundance below that point, 3.63%, 0.89%, and 0.83%, respectively. This possibly reflects the more open nature of the last 3 stations.

Discus patulus (Deshayes, 1830)

Collecting sites: 1(41), 2(1), 4(1), 5(3), 8(1), 9(11)

Another species with distinct decaying-woods affinity (Hubricht, 1963; Pilsbry, 1948). There was a distinct preference for the heavily shaded portions of the upper valleys, especially the lower, moist slopes thereof. The percentages by stations were: 22.33, 1.25, 0.97, 1.92, 1.63, and 8.14, respectively. The presence of the relatively large population at station 9 probably was in response to the dense shade and abundance of moist, decaying wood.

Discus bryanti (Harper, 1881)

Collecting site: 9(1)

Although this is characteristically a woodland species, our siftings of forest floor debris did not disclose its presence at any of the upper stations. At the 2 lower stations, where the population percentages ran 1.63 and 1.20, the specimens were associated with decaying wood. From past observations, the senior author feels that this and other *Helicodiscus* and related species tend to avoid *Rhododendron.* Consequently, since *H. parallelus* has been found at 5000 feet elevation in Tennessee (Pilsbry, 1948), the apparent restriction to the lower valleys may be correlated with the marked decrease in *Rhododendron* at those stations. Basch *et al.* (1961), however, found the species more common on flood plains.

Punctum minutissimum (Lea, 1841)

Collecting site: 7(2)

Our specimens were found beneath a deep pile of decaying hardwood leaves. According to Morse (in Pilsbry, 1948), this minute species prefers the "rotten bark of beech trees," a common tree in the study area, although somewhat scattered. Our scanty records, of course, did not allow us to corroborate Morse's statement.

Philomycidae

The two genera and 4 species of these rather typical eastern slugs made up 2.16% of the total collection, with *Pallifera* accounting for 1.40%, and *Philomycus* for 0.76%. By species, the following data were obtained: *Philomycus carolinianus* 0.17%, *P. flexuolaris* 0.58%, *Pallifera dorsalis* 1.18%, and *Pallifera fosteri* 0.23%.

Philomycus carolinianus (Bosc, 1802)

Collecting sites: 1(1), 10(2)

Only collected from the space between the bark and trunk of decaying hardwood logs on the flood plains and lower slopes, our records corroborate Branson's (1962) conclusion that this is a flood plains species. It probably occurs throughout the system. At the 2 localities, *Philomycus carolinianus* accounted for 0.97% and 3.12% of the fauna. Ingram (1949) found this slug in New York beech-hemlock associations, but observed that it avoided hemlock logs.

Philomycus flexuolaris (Rafinesque, 1820)

Collecting sites: 4(4), 8(2), 9(3), 12(1)

Long considered a subspecies of *Philomycus carolinianus* (Pilsbry, 1948, and others), Hubricht (1951) demonstrated the distinctness of this large brownish slug. Ecologically it is also distinct, since the preferred habitat is beneath stones and in rock fissures in the upland slopes. All of our specimens were found beneath logs, lying on sand, stone, or under rocks. In the station order shown above, the percentages ran 3.88, 3.27, 2.22, and 1.81.

Pallifera dorsalis (Binney, 1842)

Collecting sites: 3(1), 6(3), 7(2), 10(1), 12(6), 13(4), 14(3)

Although widespread in the valley system, this form had a rather decided preference for the lower stations. It was found on the lower slopes and on the flood plains beneath decaying leaves, along the edges of logs, and beneath stones. Dimelow (1962) found *Pallifera dorsalis* common in Nova Scotian deciduous leaf litter. The percentages were: 2.56, 2.63, 1,14, 1.56, 10.90, 3.57, and 2.50.

Pallifera fosteri F. C. Baker, 1939

Collecting sites: 3(1), 7(2), 10(1)

The external and internal anatomy of these specimens was in essential agreement with the findings of Grimm (1961) and Webb (1952). From past observations (Branson, 1962), it is apparent that this form is strictly a species of very moist flood plains. All of our specimens were removed from decaying logs in mud flats.

Pupillidae

Only 2 specimens of one species were collected. *Gastrocopta* is not in general a well-adapted mountain genus, although certain sections of the genus are. The species discussed below, for example, seems to be absent from the higher parts of the Allegheny Mountains (Pilsbry, 1948), and Chan & Kemp (1930) reported the species as only locally abundant in an Indiana locality. At lower elevations, *G. contracta* prefers mesic situations under dead woods and leaf mold (Basch *et al.*, 1961). In our study, *Gastrocopta* comprised only 0.11% of the total fauna.

Gastrocopta contracta (Say, 1822)

Collecting sites: 2(1), 9(1)

The percentage composition at station 2 was 1.75, at station 9 it was 0.74.

Cionellidae

This family is represented in North America by a single widespread species, *Cionella lubrica* (Müller). In this study it represented 1.05% of the fauna, all of our specimens being secured from the moist, heavily-shaded spots at each station, beneath thick layers of damp to wet decaying leaves.

Cionella lubrica morseana Doherty, 1878

Collecting sites: 1(1), 2(4), 7(2), 8(1), 9(5), 10(1), 12(1)

The following percentages were calculated for the above stations: 0.97, 7.01, 1.14, 1.63, 3.70, 1.56, 1.81.

AQUATIC SPECIES

It has often been observed that slightly alkaline waters are more productive of mollusks than soft ones. However, very few reports present chemical characteristics of the water from which gastropods were collected. Shoup (1943), studying various streams in the Obey River Drainage, Tennessee, found that streams flowing over sandstones of the Lee Formation were in general poor in bicarbonates, some of them as low as 2 to 6 parts per million. According to his findings, streams with bicarbonates below 20 ppm possessed depauperate mollusk faunas.

In the discussion which follows, it will be noted that mollusks were entirely lacking at all of the upland stream stations, not appearing before station 11. A glance at Table 1 will reveal very low bicarbonate in the crystal clear water until station 11, where the stream leaves the Lee Formation, and where the bicarbonate reaches a level above 40 ppm.

There are, of course, other considerations. Many aquatic snails are invariably associated with rooted vegetation, such as *Campeloma* (Allison, 1942; Bovbjerg, 1952), *Lioplax*, and certain species of *Physa* (Bickel, 1965). Since the water in our study area is subject to much fluctuation in depth, and probably also because of low carbonate content, rooted plants are very scarce to absent. In other words, the type of marginal habitat required by amnicolid and physid snails is lacking in the headwater situations, but becomes progressively more available downstream.

In our study 4 families of aquatic snails were encountered, although the first form discussed is actually amphibious.

Lymnaeidae

Lymnaea humilis Say, 1822 (= *L. dalli* F. C. Baker), the single species (7 specimens) collected by us at station 11, comprised 0.41% of the total fauna, and 7.29% of the fauna at the collecting site. As indicated above, this is an amphibious form; our specimens were found crawling on vertical sandstone some 5 feet above the water. This is apparently common, as Baker (1911) indicated that the species was "generally out of water on sticks and stones or mud flats."

Physidae

Only a single species in this nearly ubiquitous family was secured, representing 0.76% of the total collection.

Physa integra Haldeman, 1843

Collecting sites: 13(5), 14(8)

The local percentages were 4.46 and 6.67, respectively. As already mentioned, Bickel (1965) has demonstrated this species' dependency upon rooted vegetation. Since the upper stations had little vegetation, its absence there could be expected. Our specimens were secured in backwater situations on decaying leaves and *Potamogeton.* Outside the study area, downstream in Red River, the species becomes abundant on *Dianthera,* where it is associated also with *Campeloma.*

Ancylidae

The ecology of this very interesting family, which accounted for 0.52% of the mollusks found by us, remains sketchy. Two species, in separate genera, were secured.

Laevapex fuscus (C. B. Adams, 1840)

Collecting site: 14(1)

Characteristically a species of lakes and slow-flowing rivers, our single specimen (0.83% of the local fauna) was removed from a dead leaf in a side-pool.

Rhodachmea elatior (Anthony, 1855)

Collecting site: 14(8)

These specimens, comprising 6.67% of the local fauna and 0.40% of the total collection, are the first collected in Kentucky since Anthony described the species from Green River. This is a rather important discovery, since Basch (1963) indicated that the species was known definitely only from the Cahaba River in Alabama. Our specimens were found on stones in a swift riffle.

Amnicolidae

Somatogyrus subglobosus (Say, 1825)

The single specimen of *Somatogyrus subglobosus* (Say, 1825) found at station 14 constituted 0.05% of the total collection and 0.83% of the local fauna. It was associated with the *Rhodachmea.*

DISCUSSION and CONCLUSIONS

Longitudinal succession in stream organisms, from headwaters downward, is a well-known principle (Odum, 1959), one which Kuehne (1962) has correlated with Horton's (1945) drainage classification as modified by Strahler (1954, 1957). Horton's system is based on stream branching, and intermittent or permanent headwater streams are classified as Order 1. The union of 2 equal-ranked streams forms one of the next highest order, but the rank of the stream is not increased by the entrance of one of lower order than itself. Kuehne's (*op. cit.*) work showed a progressive increase in the average number of fish species present with an increase in stream order, and he suggested this relationship reflected adaptations to local conditions.

With these studies in mind, we decided to sample mollusk populations to test the hypothesis that valleys themselves could be ranked by order, which in turn would be reflected in the terrestrial fauna. The correlation with stream order is obvious in the aquatic forms (see above). In terrestrial species there also seems to be a definite correlation between valley order and number of species present (Figure 3). The average number of species at the upper 7 stations was 17.3, contrasted with 20.6 at the lower 7. Figure 4 shows the distribution of all species collected, thereby demonstrating longitudinal succession. None of the species was restricted to order 1 or order 2 valleys, but 4 species, *Mesodon thyroidus, Mesomphix inornatus, Mesomphix cupreus,* and *Retinella carolinensis,* were found only in order 3 and 4 valleys. Several of the other species, such as some *Paravitrea,* may also be restricted to the larger systems.

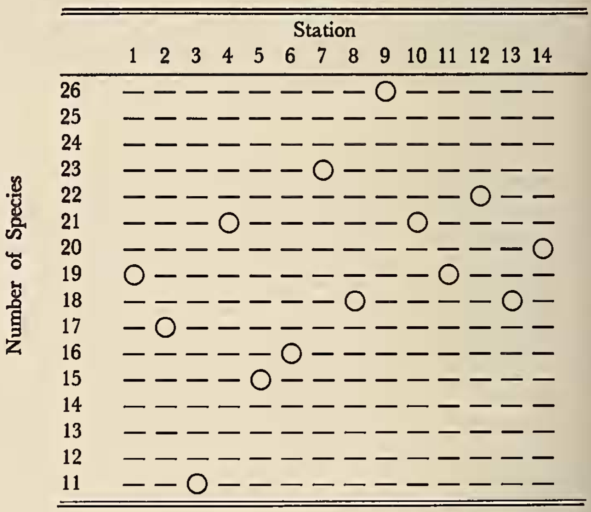

Figure 3

Graph showing Species Abundance per Station.
Average for upper 7 stations: 17.3; average for lower 7 stations: 20.6.

Another aspect of longitudinal succession observed was that of relative abundance. Roughly, 4 main patterns were observed (Figure 5): most abundant in order 1 and 2 valleys with decreasing abundance downgrade (*Ventri-*

	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stenotrema evardsi	○	○	○	○	○	○	○	○	○	○		○		○
Stenotrema stenotrema	○	○		○	○	○	○	○	○	○	○	○	○	○
Stenotrema angellum												○		
Stenotrema barbatum	○	○	○	○		○	○		○	○	○	○		
Stenotrema leai				○		○	○		○		○		○	○
Mesodon thyroidus									○		○		○	○
Mesodon zaletus														○
Mesodon appressus	○	○	○	○	○	○	○	○	○	○	○	○		○
Mesodon sayanus	○	○		○	○	○	○	○	○	○	○	○	○	○
Mesodon ruglei	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Triodopsis tridentata	○	○	○	○	○	○	○		○	○	○			
Triodopsis fraudulenta												○	○	○
Triodopsis denotata							○		○	○			○	
Triodopsis albolabris	○			○	○	○	○	○	○	○	○	○		
Haplotrema		○		○		○	○	○	○	○	○	○	○	○
Euconulus							○					○		
Retinella wheatleyi				○	○	○	○		○	○	○			
Retinella indentata	○													
Retinella carolinensis							○	○	○			○		
Retinella cryptomphala	○	○	○	○	○	○	○	○	○	○	○	○	○	
Mesomphix inornatus								○	○	○	○	○	○	○
Mesomphix perlaevis	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Mesomphix vulgatus									○					
Mesomphix cupreus		○							○	○	○	○	○	○
Mesomphix capnodes													○	○
Paravitrea placentula									○					
Paravitrea multidentata									○		○			
Paravitrea capsella									○					
Paravitrea lafuzi		○												
Paravitrea sceada									○					
Gastrodonta	○	○		○	○	○	○		○	○		○	○	
Ventridens	○		○	○	○	○	○	○	○	○		○		
Zonitoides nitidus	○	○												
Zonitoides arboreus	○	○												
Striatura	○		○	○	○			○			○		○	
Derocerus	○			○				○						
Anguispira											○	○	○	○
Discus patulus	○	○		○	○			○	○					
Discus bryanti								○	○					
Punctum							○							
Philomycus carolinianus	○									○				
Philomycus flexuolaris				○				○	○	○				
Pallifera dorsalis			○			○	○			○		○	○	○
Pallifera fosteri			○				○			○				
Gastrocopta		○							○					
Cionella		○					○	○	○	○		○		
Lymnaea											○			
Physa													○	○
Laevapex														○
Rhodachmea														○
Somatogyrus														○

Figure 4

Graph showing Occurrence of Mollusks at Collecting Stations.

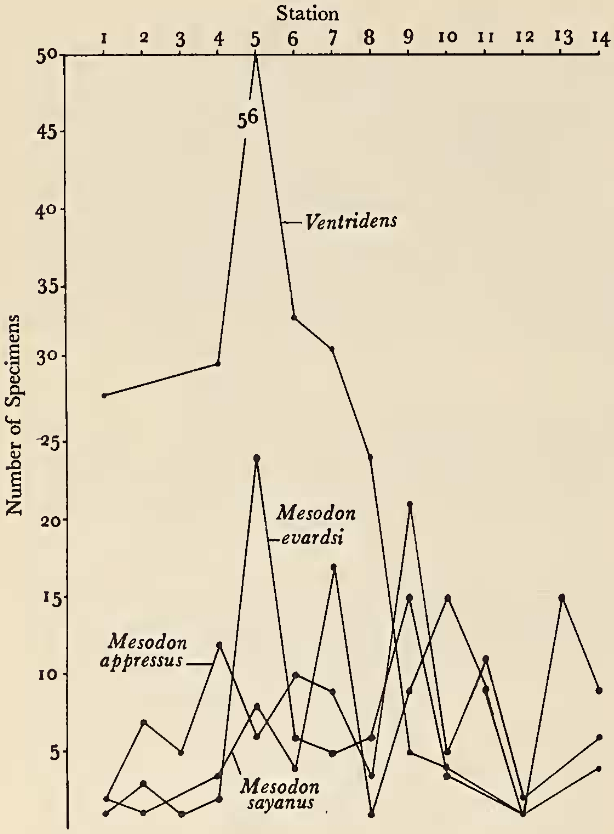

Figure 5

Graph showing Distribution by Numbers in Four Molluscan Species.

dens), most abundant in order 2 and order 3 valleys (*Stenotrema evardsi*), most abundant in order 4 valleys (*Mesodon sayanus*), and more or less abundant throughout the system (*Mesodon appressus*). Other species could have been selected, but these are representative. Some of the sporadic variation may be the result of local differences in edaphic conditions (Burch, 1955) and, indirectly, the occurrence of favorable plant associations (Burch, 1957).

A final, and perhaps more important, observation is illustrated by Figures 6 and 7. It appears that when 2 snail species with similar habitat requirements occur together sympathically one or the other's population is held in abeyance, probably according to which species is favored by the particular environment. In the case of *Mesodon appressus,* which we have already indicated produces its largest populations in the uplands, versus *M. sayanus* (Figure 6), it can be seen that *M. sayanus* is

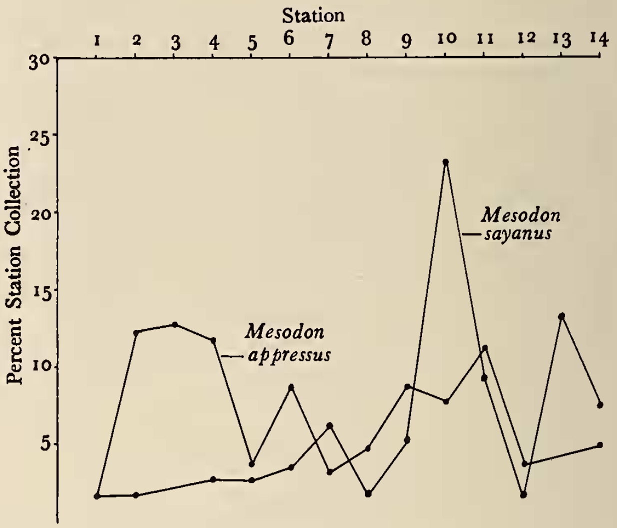

Figure 6

Graph showing Station Percentages for *Mesodon appressus* and *Mesodon sayanus.*

held to relatively small populations in the uplands, whereas there is a tendency to reversal in order 3 and order 4 valleys. In *Mesomphix perlaevis* versus *M. inornatus* the contrast is even more striking (Figure 7). These competitive relationships need intensive study.

Comparisons of disturbed versus undisturbed areas showed no positive correlations.

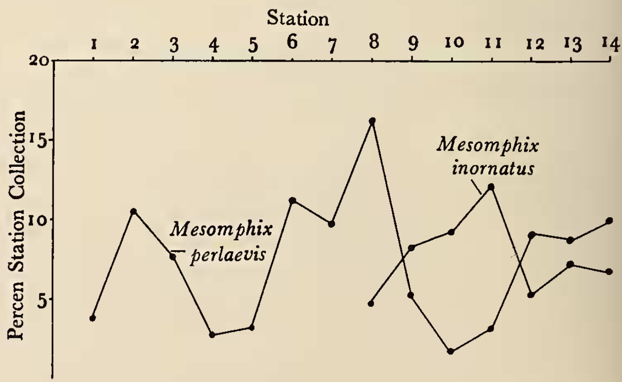

Figure 7

Graph showing Station Percentages for *Mesomphix perlaevis* and *Mesomphix inornatus.*

SUMMARY

1. Fourteen randomly selected stations, located in Wolfe and Powell Counties, Northern Kentucky, were systematically searched for terrestrial and aquatic mollusks, the habitat conditions at each station were detailed, and information on plant associations and water chemistry secured.
2. Twelve families, 26 genera, and 52 species, two apparently new, were collected.
3. The family Polygyridae is the dominant taxon present in the study area, 47.26% of the total fauna. It is followed by the Zonitidae, 38.52%. The remaining 14.22% of the fauna is unequally divided between the other 10 families.
4. The percentage-composition of the total fauna was calculated for each genus, showing *Mesodon* (23.67%), *Stenotrema* (15.03%), *Mesomphix* (13.44%), and *Ventridens* (12.74%) to be the dominant ones.
5. The number of each species collected per station is presented; percentages were calculated as regards the total fauna and the faunas at each station. *Mesodon ruglei* (10.74%) and *Ventridens demissus* (12.74%) are the two dominant species in this region.
6. Observations on habitat and ecology are presented in discussions of individual species.
7. Analysis of ecological distribution demonstrates a positive correlation between the number of species present and valley magnitude. No species were restricted to valleys of first or second order, but several were found only in order 3 or order 4 valleys.
8. Correlated with low concentrations of calcium carbonate in order 1, 2, and 3 streams, aquatic mollusks are restricted to order 4 streams in the study area.
9. Relative abundance observations disclosed 4 main patterns: (a) greatest abundance in order 1 and 2 valleys, decreasing in abundance downgrade; (b) greatest abundance in order 2 and 3 valleys, decreasing up- and downgrade; (c) greatest abundance in order 4 valleys, decrease upgrade; and (d) abundant throughout the system. Examples of each type of distribution are included.
10. Sympatric species with similar ecological requirements, according to local environmental conditions, mutually affect populations, either by suppressing an associated species or being suppressed by it.

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